AfriqAir and CAMS-Net General Meeting

Tuesday 7 March 2023 - Friday 10 March 2023

Carnegie Mellon University - Africa Campus, Kigali, Rwanda

AfriqAir

General Meeting and Air Quality Conference

March 7-10, 2023

CMU-Africa, Kigali, Rwanda

Book of Abstracts

Contents

Poster Session / 3

Ambient PM2.5 monitoring from the Gold Mine Tailings to Assess the Human Health Effects in the Community of eMbalenhle, South Africa

Author: Nomsa Thabethe[1]

Co-authors: Daniel Masekameni [1]; Derk Brouwer [1]; Thafadzwa Makonese [1]

[1] *University of the Witwatersrand*

Corresponding Author: nomsa.thabethe@gmail.com

Particulate Matter (PM2.5) pollution remains a significant air pollution problem in South Africa and worldwide, posing serious human health effects to exposed communities. This study presents an overview of the human health impacts posed by exposure to PM2.5 from Gold Mine Tailings (GMT)in the community of eMbalenhle. PM2.5 concentrations were measured at both the GMT (source) and at the community (receptor) in eMbalenhle using the Low-Cost Monitors (Clarity Note-S). The measured PM2.5 data was analysed using OpenAir data analysis software. The samples of ambient particulate matter at both the source and receptor were collected with the University of North California (UNC) Particle samplers and were analysed using Computer Controlled Scanning Microscopy (CCSEM) techniques to perform size measurements, chemical composition on individual particles and sources of ambient particulate matter. The Human Health Risk Assessment Model was then applied to estimate the human health impacts of exposure to PM2.5 from the GMT on different life-stages in the community of eMbalenhle. The results show the high levels of concentrations at the receptor than the source. The findings further indicates that the community of eMbalenhle was exposed to the PM2.5 concentrations exceeding the ambient PM2.5 South African National Ambient Air Quality Standards (NAAQS) and the World Health Organisation (WHO) Air Quality Guidelines which were set to protect both the environment and human health. The study concluded that particle dispersion from the source to receptor has a great impact when assessing the human health impacts to PM2.5 exposure.

Poster Session / 4

Towards an Improved Air Quality in Nairobi City: Insights from the Urban Profile and the Vulnerability Scoping Studies

Author: Tom Randa[1]

Co-authors: William Avis [2]; Winnie Asiti [3]

[1] *African Centre for Technology Studies*

[2] *University of Birmingham*

[3] *Climate Analytics*

Corresponding Author: tomranda12@gmail.com

Most developing cities struggle with deteriorating air quality challenges and Nairobi is such a city. This paper explores the state of air quality in Nairobi city drawing from the outcomes of the Nairobi Urban profile and the Vulnerability scoping studies conducted under the A system Approach to air pollution in East Africa project. Using these studies'outcomes, the paper aims to provide insights into the state of air pollution, the vulnerability scope of the residents and users, and give appropriate recommendations. The outcomes indicate that both indoor and ambient air pollution levels in the city regularly exceed WHO guideline amounts with the PM2.5 concentrations indoors measuring an average of 43 ± 19 µg m3 and peaking at 47 ± 14 µg m3 most of the time in the city center. The outdoor concentration levels of PM2.5 recorded larger concentrations, averaging 54 ± 22 and peaking at 61 ± 21, which is consistently at an unhealthy level. The air pollution levels are too high, exceeding the WHO guidelines in the city's largest Dandora dumpsite affecting more than 3.5 million city residents living within a radius of 10 Kilometers. The site recorded PM2.5 concentrations of about 47.4 ± 9.5 µg/m3 and a peak concentration of 94.5 ± 32.6 µg/m m3 most of the days. Despite this evidence, the city has no continuous and robust air quality monitoring system, and thus a data gap to conclusively ascertain the overall air quality and its impacts on human and environmental health. The study, therefore, recommends a quick establishment of a robust and reliable air quality monitoring and management system in the city besides the policy, strategic infrastructural expansion, city decongestion, proper waste management, and strategic traffic management by the Nairobi city-county government working with its strategic partners and stakeholder towards a holistic air quality improvement in the city.

Poster Session / 5

Characterization of the level of exposure of households using improved stoves to indoor air pollution in cities of Sahelian countries : case of the city of Ouagadougou

Authors: Kayaba HARO[1]; Oumar Sanogo[2]

Co-authors: Abdel Anziph. S. Khalid NOUROU [3]; Antoine BERE [4]; Bernard Nana [5]; Issoufou Ouarma [4]; Lucman KOALA [3]; Tizane DAHO [4]

[1] *Centre National de la Recherche Scientifique et Technologique (CNRST)-Burkina Faso*

[2] *Institiut de Recherche en Sciences Appliquées et Technologies du Centre National de Recherche Scientifique et Technologique (IRSAT/CNRST),*

[3] *2Laboratoire de Physique et de Chimie de l'Environnement de l'Université Joseph KI ZERBO (LPCE/UJKZ)*

[4] *Laboratoire de Physique et de Chimie de l'Environnement de l'Université Joseph KI ZERBO (LPCE/UJKZ)*

[5] *Ecole Normale Superieur/Universite Joseph KI-ZERBO*

Corresponding Author: kayabaharo@gmail.com

This study focuses on the characterization of household exposure levels to indoor air pollution in the city of Ouagadougou. The pollutants concerned are carbon monoxide (CO) and particles with a diameter of less than 2.5 microns (PM2.5) emitted by fuel combustion. Thirty (30) households including 10 improved stoves, 10 traditional stoves and 10 gas stoves were selected as the sample for our study. The measurements were made during the rainy season (August-October 2021) in a real kitchen situation following the procedure as described by Kitchen Performance Test (KPT) and the IAP-Metter instruction guide. The different types of fuel encountered in this study include liquefied petroleum gas, charcoal and wood. The results show that the average carbon monoxide concentrations obtained for improved stoves, traditional three-stone stoves and gas stoves are respectively 184.567; 105.315 and 93.6µg/m3 during the cooking period. The PM2.5 concentrations for these same stoves were 186.37; 1846.3 and 27.362 µg/m3 for the improved stoves, traditional three-stone stoves and gas stoves respectively. The carbon monoxide concentrations are well above the threshold specified by the World Health Organization (WHO) (30 mg/m3 for 1-hour exposure ; 10mg/m3 for 10-hours of exposure). As for PM2.5, the concentrations are also very high even if the duration of exposure does not fit with the WHO data. It was noted that improved households expose their users more to CO than other types of households. These high levels of exposure to pollutants represent a danger for women and children, especially since women are practically in the kitchen with their children sometimes during the cooking period.

Poster Session / 6

Air quality in West African cities: case of passive sampling of SO2, NO2 and BTEX in the city at Ouagadougou

Author: OUARMA Issoufou[1]

Co-authors: Antoine BERE [2]; Bernard Nana [3]; Guy Christian TUBREOUMYA [2]; Jean KOULIDIATI [2]; Kayaba HARO [4]

[1] *Centre universitaire de Banfora*

[2] *Laboratoire de Physique et de Chimie de l'Environnement (LPCE), Université Joseph KI-ZERBO, Ouagadougou, Burkina Faso*

[3] *Ecole Normale Superieur/Universite Joseph KI-ZERBO*

[4] *Centre National de la Recherche Scientifique et Technologique (CNRST)-Burkina Faso*

Corresponding Author: ouarma.issoufou@hotmail.fr

As in northern cities, transport is one of the main causes of air quality degradation in southern cities, especially in West African cities. Very few studies have focused on air quality in these cities, particularly in Ouagadougou. As a result, there is a lack of scientific data to evaluate air quality. The last campaign to monitor pollutants in the city of Ouagadougou was carried out in 2007. It showed that air quality is a concern and that it is likely to deteriorate further due to the rapid growth of the population and the rapid evolution of the vehicle fleet based on the massive importation of second-hand vehicles. We present here the results of a measurement campaign using passive sampling tubes, over the period from 15 to 29 September 2015, aiming to update data on the state of air quality in the city of Ouagadougou. The pollutants concerned are: nitrogen dioxide (NO2), sulfur dioxide (SO2), and BTEX (benzene, toluene, ethylbenzene and xylenes).

Poster Session / 7

SOURCE IDENTIFICATION AND METAL ANALYSIS OF FINE PARTICULATE MATTER (PM2.5) IN AN INDUSTRIALIZED URBAN AREA OF LAGOS STATE NIGERIA

Author: Emmanuel Chiedu[1]

Co-author: James Okuo [2]

[1] *Federal Institute of Industrial Research Oshodi (FIIRO) Lagos State Nigeria.*

[2] *University of Benin*

Corresponding Author: emmychiedu2010@yahoo.co.uk

ABSTRACT

Gaseous pollutants and particulate matter are released into the atmosphere at concentrations above their normal ambient level; this is caused by the increasing human activities which eventually have a measurable effect on humans, animals and plants. The size of particles is directly linked to their potential for causing health problems. Fine particles (PM2.5) are mainly generated by combustion processes including emissions from motor vehicles, combustion of fossil fuel for power generation and large industrial processes such as ore and metal smelting. They may also include natural emissions such as fine windblown soils, sea spray and smoke from biomass burning.

The fine particulate matter (PM2.5) was collected using Casella Cel-712 Microdust Pro Real-time Dust Monitor with polyurethane foam (PUF) and a glass fibre filter (GFF). The PM2.5 levels obtained ranged from 14.00 to 32.67µg/m3during wet season and 18.67 to 34.67µg/m3during dry season. Trace elements were determined using Atomic Absorption Spectrophotometer for the heavy metals and Flame Photometer for the light metals.

The Enrichment Factor (EF) analysis showed very high enrichment for the elements; Pb, Cd, Cr, Cu, Ni, Na, K, Mg, and Ca in the fine fraction (PM2.5) which is a signature of anthropogenic sources. Principal Component Analysis (PCA) studies explained three common contributing sources of fine particulates (PM2.5) such as entrained soil, sea salt and combustion.

Poster Session / 8

AIR QUALITY INDEX AND HEALTH DYNAMICS IN CHANGING CLIMATE OF THE NIGER DELTA REGION OF NIGERIA

Author: Felix Paul[1]

[1] *University of Uyo, Uyo*

Corresponding Author: flexipaul001@gmail.com

ABSTRACT
The study was set to assess the effect of air quality index on health dynamics in the Niger Delta Region of Nigeria. Epidemiological data was collected from the Federal Ministry of Health and from various State Ministries of Health, in relation to ambient Air Quality data of the States and National Ambient Air Quality Standard data. The study covered a period of ten years, ranging from 2011 to 2021. The standard deviation (SD) and variance was determined while the estimated coefficient of variation (CV%) was used to assess the variation in the concentration levels of the air pollutant monitored. ArchGIS software was used to generate the pollutants concentration maps, while Sim-air quality software was used to calculate the air quality index of the air pollutants. It was found that a total number of 83,579 disease cases were reported during 2011 to 2021, out of which 103 patients died. The diseases found to be prevalent in the study area are pneumonia, pulmonary tuberculosis, upper respiratory tract infection (URT), cerebrospinal meningitis (CSM), and whooping cough (pertusis). The ambient air quality observed in the states (lead = 0.1115 ppm/year, particulates = 10 ppm/year, N-oxides = 2.55 ppm/year, SO2 = 1 ppm/year, VOC = 82.78 ppm/year) was far worse than the World Health Organization Air Quality Standard (Lead = 1 × 10-6 ppm/year, particulates = 105 ppm/year). This study recommends that environmental education should be intensified and air quality monitoring stations installed at strategic locations for continuous monitoring and evaluations.

Poster Session / 9

The usefulness of citizen science in revolutionizing and advancing air quality campaigns in Ghana

Author: Collins Gameli Hodoli[1]

[1] *University of Environment and Sustainable Development and Clean Air One Atmosphere*

Corresponding Author: cghodoli@uesd.edu.gh

Air pollution is currently the second leading health risk factor for deaths in Africa contributing to millions of premature deaths. Major sources of air pollution identified in Africa are vehicular emissions, slash-and-burn agricultural practices, poor waste management practices, wind-blown dust, industrial emissions and dirty energy sources used in fuel-poor homes for cooking and heating. The current research trends have shown that household air pollution is a major contributor to more than half of premature deaths reported in Africa.
Despite these devastating findings, public knowledge of air pollution and related health impacts is very limited in these environments. This is potentially linked to sporadic air quality monitoring capabilities and the huge limitation of meaningful communication of reported air quality data from local environmental regulatory agencies.
Citizen science has the potential to bridge scientific gaps specifically in environments with limited expertise and tools for advancing scientific research. Participatory research involving interested community members can support capacity development in specific scientific fields and contribute to advancing awareness creation and highlight critical areas of severe gaps for knowledge development in science. In the case of air quality monitoring, citizen science has the potential to revolutionize air quality campaigns if this is linked to capacity building targeted at air pollution science research and mitigation.
In Africa, low-cost sensors (LCS) for air quality monitoring are rapidly expanding. This has the potential to shift the paradigm regarding air quality monitoring, meaningful data communication, and air pollution mitigation.
In this piece, critical consideration has been given to the usefulness of participatory science to deploy,

manage and supervise LCS and the subsequent meaningful communication of the reported data. It was found that accessible, reliable, near-real-time air quality data via the open-source platform Yakokoe can promote public knowledge of air pollution in Ghana and similar environments. The results indicate that these approaches can influence behavioural changes if linked to air pollution control and management through extensive public engagement, education and empowerment.

Poster Session / 10

Angstrom exponent and turbidity coefficients from broadband irradiance as indices of atmospheric pollution levels over Save (Benin Republic) in Southern West Africa during DACCIWA field campaign

Author: Olawale Abiye[1]

Co-authors: Mumeen Tajudeen [2]; Oluseyi Akinola [2]; Phebe Ogunniran [2]

[1] *Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife, Nigeria*

[2] *Department of Physics and Engineering Physics*

Corresponding Author: waleabiye@gmail.com

This study utilized solar irradiance measurements to estimate spectral atmospheric turbidity characteristics using Gueymard's Multi-coefficient Approach and compared with experimental measurement. The objective was to assess the reproducibility of the approach for estimating atmospheric turbidity from less resource-intensive irradiance measurement during African Monsoon period, and relate it to air pollution level. Seven saturation vapour pressure models and routine meteorological data from Dynamic Aerosol-Chemistry-Cloud Interaction in West Africa (DACCIWA, June/July, 2016) field campaign were used to determine precipitable water vapour (PWV) over Save, Benin Republic. In-situ measurements of spectral-dependent aerosol optical and microphysical properties were taken from Cimel Sun-photometer almucantar scanning of the atmosphere in the same location. Clear-sky measurement of broadband Beam Normal Irradiance (BNI) from Copernicus Atmospheric Monitoring Service (CAMS McClear) and in-situ sun-photometer measurement of stratospheric ozone, nitrogen dioxide column and water vapour were used to compute Angstrom and Schuepp's turbidity parameters (coefficient β and exponent α). Model estimates of PWV falls into three categories of values; high- (3.75 –9.1 cm), medium- (3.6 –4.96 cm) and low- (2.3 –3.5 cm) ranges with a correlation of at least 0.99 among the medium-range models. Case studies of the highest (β = 0.32, α = 0.67) and least (β = 0.084, α = 1.2) turbid days correlates with high concentrations of carbon monoxide and ozone pollution. Simulation of radiative transfer of sunshine on both days also reveals the corresponding attenuation of solar irradiance at the surface. Experimental and model estimates of PWV and turbidity coefficient showed that the broadband method is a relatively accurate and alternative approach for assessment of atmospheric turbidity condition.

Poster Session / 11

Assessment of Low-Cost Sensor Correction Factors and Development of of a Global Gaussian Mixture Regression Model for Correcting Optical Low-Cost Sensor Data

Author: Garima Raheja[1]

Co-authors: Albert Presto [2]; Allison Hughes [3]; Benjamin Essien [4]; Collins Hodoli [5]; Dan Westervelt [1]; Emmanuel Appoh [4]; James Nimo [3]; Michael Giordano [6]; R Subramanian [7]; Robert Pinder [8]; Sabi Kokou [9]; Sehrish Mastoor [1]; Sonla Hezouwe [9]

[1] *Columbia University in the City of New York*

[2] *Carnegie Mellon University*

[3] *University of Ghana*

[4] *Ghana EPA*

[5] *Clean Air One Atmosphere*

[6] *AfriqAir*

[7] *Qatar Environment and Energy Research Institute*

[8] *US EPA*

[9] *University of Lome*

Corresponding Author: garima.raheja@columbia.edu

Air pollution is a leading cause of global premature mortality, and is linked to more than 1 million premature deaths in Africa per year. Advancements in low-cost sensors (LCS) are helping bridge the data gap left by historically expensive and technically challenging reference-grade monitors. While novel data science techniques are being used to develop correction factors for LCS, these studies generally (1) use co-locations with expensive reference-grade monitors, (2) utilize temperature, humidity and other measurements to account for variation in hygroscopicity and optical properties, and (3) are often local in scope, limited to one city or metro area.

Can we use correction factors developed at one location, in another? We use co-locations from 5 cities (Palisades, NY; Accra, Ghana; Lomé, Togo; Kinshasa, DRC; Kolkata, India) at varying climatologies and distances to assess the performance of Multiple Linear Regression, Random Forest and Gaussian Mixture Regression correction factors, and compare them to published correction factors in the literature.

Additionally, we develop a Global Gaussian Mixture Regression (GMR) machine learning model trained on co-locations from 15+ cities in the Clean Air Monitoring and Solutions Network (CAMS-Net). GMR has proven successful for correcting LCS data: in Kinshasa, the GMR-corrected Purple Air data resulted in R2 = 0.88 when compared to the MetOne BAM-1020, and in Accra, the GMR lowered the Mean Absolute Error of Clarity data from 7.51 µg/m3 to 1.93 µg/m3. The wide breadth of the Global GMR allows for correction of LCS data without the need for a local co-location; we present an open-source dashboard that enables the correction of data from 20,000+ PurpleAir and Clarity sensors around the world.

Poster Session / 12

REAL WORLD SENSOR APPLICATION

Author: Wandji Danube Kirt Ngongang[1]

[1] *UNEP*

Corresponding Author: wandjidanube@gmail.com

Air pollution is one of the major risk factors for human well-being in Low- and Middle-Income Countries (LMICs) in sub-Saharan Africa. Tackling challenges to improve air quality management is, in part, due to limited monitoring infrastructure. AS a result, the burdens of air pollution are likely to be underestimated because of the limited ground monitoring data in affected regions.

The application of miniaturized air quality sensors when set in the real-world environment offers hope to many developing regions to support policy development and action. Their application is mainly affected by factors less associated with technical performance and more related to factors such as security of the targeted location, the ambient conditions with real emission sources, poor to inexistent internet infrastructure and unreliable power supply. The above-mentioned factors coupled with environment factors like rain, insects and high dust emissions tend to affect the operation of the sensor leading the data gaps.

Pilot projects in Africa, for instance, have proved that logistical challenges impact the operation of sensors, site surveys, maintenance and operational arrangements are central elements to be agreed upon prior to deployment if monitoring is to be sustained beyond a few weeks.

Designing instruments for the unique conditions in many developing countries is a critical step towards bridging the data gap. UN collaborations with manufacturers like Sailhero (China), IQair (Switzerland), Praxis (UK), Kunak(Spain), among others, have yield lessons that is shaping the UNEP/GEMS/Air programme that aims to support LMICs.

This session will provide real-world cases from Africa of how sensors have been used to influence policy action. It will demonstrate innovations and modalities that are address challenges with the uptake of sensors in the regions and provide an overview of the UN open Data Management System to facilitate data gathering and management among sensor communities.

Poster Session / 13

Importance of sampling strategy on diffuse solar energy prediction in Cameroon

Author: yaulande DOUANLA ALOTSE[1]

[1] *Institute of Mathematics and physics of Porto-Novo, Benin*

Corresponding Author: yaulande.douanla@imsp-uac.org

A key role of the modeling process is to identify the relationship between the inputs and the target variable(s) (outputs) set to study a given phenomenon and also to predict the outcome of that phenomenon. In the context of machine learning, in addition to the concern about feature selection, there is a second concern about the sample size needed for model design.
However, in the literature only few projects have focused on determining optimal sampling approaches. Thus, in this study, the objective is to propose a robust validation procedure for the daily prediction of direct normal irradiation under clear sky conditions (DNI) in Cameroon. So, considering the data of the different types of aerosols (sea salt, sulphate, desert dust, black carbon and organic) and other meteorological variables collected and 181 points of the study area, an automatic learning model based on the Extreme gradient boosting (XGBoost) has been designed using a training set collected from the 9 different clusters.
After what we invested in proposing some optimal approaches for the selection of the validation set based on the derivatives of the K-median. In this respect the methods named maxkmed4 and maxkmed5 have respectively allowed to form a more and less compact data set independently of the sample size. It was also concluded that for a local prediction the sample obtained from maxkmed5 will be the best adapted because being the less compact, it reflects the most the characteristics of the study area according to the test n 7 different areas.

14

Hands-on Low-cost sensor Training

Corresponding Author: mike@afriqair.org

Hands-on LCS basics, calibration, data analysis, and companion programs

15

OpenAQ Data access and sharing

16

Hands-on Regulatory-grade monitor trainings

17

Satellite data access and basic usage

18

Hands-on simple modeling tools training

19

AirQo Data Training

20

CMU-Africa and AFRETEC Welcome

21

CAMS-Net Welcome/Intro

22

Keynote panel: Recent Advances in Air Quality in Africa + Q/A

Co-authors: DIDIER NTWALI [1]; Daniel Westervelt [2]; Engineer Bainomugisha [3]; N'datchoh Evelyne Toure [4]

[1] *Rwanda Space Agency, Earth and Space Science Division, Rwanda Climate Observatory*

[2] *Columbia University*

[3] *AirQo*

[4] *Université Felix Houphouet Boigny Abidjan*

Corresponding Authors: baino@airqo.net, dntwali@space.gov.rw, danielmw@ldeo.columbia.edu

Keynote speakers:
Evelyne Toure
Engineer Bainomugisha
Dan Westervelt
Didier Ntwali

23

AfriqAir announcements

Afri-SET
Breathe Accra
Rockefeller

24

CAMS-Net Presentations

Seed grant presentations

25

Breakout groups

26

Side meetings

TBD

Poster Session / **28**

Adoption of Electric Vehicles to cut down greenhouse gas emissions into the atmosphere: Case of Kenya

Author: Willy Tounsi[1]

Co-author: Danube Wandji [2]

[1] *British Higher Institute of Sciences and Technolgy*

[2] *United Nations Environment Programme, Nairobi, Kenya*

Corresponding Author: tounsi.fokui@ubuea.cm

Burning gasoline and diesel fuel create harmful byproducts like nitrogen dioxide and carbon dioxide. In 2020, the worldwide transportation sector generated over 7.3 billion metric tons of carbon dioxide emissions, making it one of the worst polluters. As a response to this, electric vehicles (EVs) are fast being adopted since they are emissions-free. According to research, the transportation sector needs to undergo a complete revolution brought on by EVs powered by no carbon emissions sources to achieve the 2050 global warming pollution target of an 80% reduction from the 1990 level (22.4 billion metric tons of carbon dioxide). Looking at Kenya, the country had a domestic transport emission of 12.343 MtCO2e in 2019 (excluding emissions from waterborne navigations), of which the roads accounted for 12.09 MtCO2e. By 2025, the government wants to see a 5% increase in EVs in the country. As strategies are being unfolded to foster EV adoption, there is a need to analyze their impact and implications. This research aims to show that, the increasing adoption of EVs in the

country will result in more pressure on the electrical distribution network, and issues of increased power losses, degraded voltages, and failure of protective equipment resulting in power outages could be observed. On the other hand, the increasing adoption of EVs will reduce greenhouse gas emissions when compared to burning fossil fuels and reduce the footprint of carbon dioxide and other pollutants associated with the transport sector.

Poster Session / 29

Daily PM2.5 concentrations levels at Agoè-Minamadou in the city of Lomé, Togo

Author: Hèzouwè SONLA[1]

Co-authors: Daniel WESTERVELT [2]; Garima RAHEJA [2]; Kokou SABI [3]

[1] *Université de Lomé/Faculté Des Sciences/Département de chimi*

[2] *Columbia university*

[3] *Université de Lomé/Département de chimi*

Corresponding Author: audesonlat@gmail.com

The increase of the Togolese population and in particular that of the city of Lomé in recent decades has led to the creation of peripheral districts such as Agoè-Minamadou (AM). As a result, various activities have been created to meet the needs of the local population. These activities have an impact on human health and on the environment through the production of air pollutants. To measure and identify the causes of the emissions of fine particulate matter (PM2.5) in the city of Lomé in Togo, a PurpleAir PA-II-SD sensor is placed in AM in order to determine the trends in PM2.5 concentrations. The first results indicate that several activities such as road traffic, wood and waste combustion, domestic activities are the likely causes of fine particles emission in the ambient air in AM. Particle measurements carried out with the PurpleAir (PA) sensor revealed the presence of PM2.5 in the air with daily concentrations varying from 0.01 to 600 µg/m3. Using the teledyne collocation technique, a correction observation was applied to the sensor data at the AM site. Based on this correction observation, the daily average PM2.5 concentrations exceeded 20µg/m3. The amounts of particulate matter produced at AM exceeded the WHO recommended thresholds (5 µg/m3) only during the hours corresponding to the burning of waste within the radius of the AM point.

Poster Session / 30

In-kitchen aerosol exposure in Korogocho Informal settlements in Nairobi City

Authors: Anderson Kehbila[None]; Cynthia Sitati[1]; Philip Osano[1]; Prashant Kumar[None]

[1] *Stockholm Environment Institute*

Corresponding Author: cynthia.sitati@sei.org

In urban set-ups, the use of charcoal as a source of energy is predominant among the urban poor (low-income earners). In the urban informal settlements such as the Korogocho slums in Nairobi, households rely on kerosene and charcoal for cooking. In some cases, it has been reported that some poorest households in these informal settlements use plastic waste, cloth rags, and other unconventional fuels due to unaffordability to access conventional sources of energy. As a result, the fuels generate high levels of harmful indoor air pollutants. This study was part of the wider project in which we assessed exposure to in-kitchen particulate matter (PM2.5 and PM10) in 60 low-income homes across 12 cities, including Nairobi (Kenya). We aim to ensure cleaner air in homes and promote the development of equitable, inclusive, social, and environmental benefits in one of Nairobi' s informal settlements as indoor environments have become more important during the Covid-19 pandemic thereby necessitating the need to ensure less exposure of households to harmful pollutants. We assessed indoor air pollution exposure by monitoring aerosol exposure in five different households in the informal settlement of Korogocho in Nairobi. We engaged stakeholders through co-designed webinars, outreach, and capacity-building activities. The study aimed at developing exposure strategies and assessing the feasibility of similar studies in other parts of the country. The results showed that fuel, kitchen volume, cooking type, and ventilation were the most prominent factors affecting in-kitchen exposure. There is an urgent need for increased awareness of improved cooking practices and minimizing passive occupancy in kitchens to mitigate harmful cooking emissions.

Poster Session / 31

Abstract on Raising Public Awareness on Air Pollution

Author: Church Essien[1]

[1] *University of Uyo*

Corresponding Author: churchmessien@gmail.com

Air pollution is a significant environmental problem that affects the health and well-being of individuals and communities around the world. In order to raise awareness of this issue and encourage action to address it, there are several strategies that can be implemented. These include:
a. Education and outreach
b. Advocacy and lobbying
c. Social media awareness
d. Collaboration with related organizations
e. Use of visual aids
f. Community engagement
Overall, a combination of these strategies can be effective in raising awareness of air pollution and encouraging action to address this important environmental issue.Personal action: Individual actions can also contribute to raising awareness of air pollution and encouraging change. This can involve simple steps such as reducing personal energy consumption and driving less, as well as supporting businesses and organizations that prioritize sustainability and environmental protection.Collaboration with other organizations: Partnering with other organizations, both within and outside the community, can be an effective way to amplify the message and reach a wider audience. This can include collaborating on educational materials, events, and campaigns, and working together to advocate for policies and regulations that address air pollution.Use of visual aids: Using visual aids, such as infographics and videos, can be an effective way to communicate information about air pollution in a way that is engaging and easy to understand. These tools can be shared through social media, presentations, and other outlets to help raise awareness and encourage action.Creating public art: Using public art, such as murals and installations, can be a creative and attention-grabbing way to raise awareness of air pollution. These works can be located in prominent places and used to educate the public about the issue and inspire action.By implementing these strategies, individuals and organizations can work together to raise awareness of the problem of air pollution and encourage action to address it.

Poster Session / 32

Air Quality Monitoring and Satellite Data Integrity Concerns in Nigeria: A Review.

Authors: Bassey Ekah[1]; Igwe-Steve Ewona[2]

[1] *University of Calabar, Calabar*

[2] *University of Cross River State former*

Corresponding Author: igweewona@gmail.com

Abstract

Most air quality indices in Nigeria are based on satellite data which do not always conform with ground based data. These statistics have also been used by the United Nations, African Development Bank including the World Bank for purposes of planning, policy formulation and to estimate health indices, over Nigeria and Africa at large without subjecting them to ground based data validation. Using these data, the World Health Organization reports that air pollution is the 4th leading risk factor for premature deaths and accounts for about 12 percent of all deaths, worldwide, reducing life expectancy by 2.2 years on average. The Organization also observed that over 80% of urban dwellers in West Africa are exposed to air quality levels that exceed WHO limits and accounts for about 7 million deaths globally. World Population Review, using 2019 data for 10 top countries with the worst air pollution- PM2.5 exposures, ranked Nigeria 5th with
70.4μg/m3 but 38th with 21.470.4μg/m3 when using 2018 data. The sharp difference is a manifestation of the weaknesses of satellite data. The pilot study carried out by Udo and Ewona from 2016 on characterization of air quality parameters in the Niger Delta Area, a project sponsored by TETFund, have further exposed the weaknesses of satellite data. Correlation indices for common pollutants produced weak values. Unfortunately, on ground based data are scanty in most African countries like Nigeria to validate such claims. The implication being that air pollution related statistics may not correlate well with actual data on ground rendering such information misleading. Nigeria is the most populous nation in Africa and according to World Population Review, Nigeria is the 39th most populous country in the world, with multiple densely populated cities that accommodate over one million people each. This paper reviews efforts made in Nigeria towards on-ground pollution monitoring and possible implications of over dependence on satellite data. Though Environmental institutions such as CAR-NASRDA and NESREA have been directed to collaborate with the global network for real-time observation and measurement of both gaseous and particulate pollutants in Nigeria, implementation efforts are far below expectation. While CARNASRDA has deployed only 11 purple Air and 5 clarity air devices between 2021 to date, NESREA has none functionally installed. This is clearly why on ground pollution data is scanty

Keywords: Satellite data, On-ground data, correlation indices, Data integrity

Panel Discussion / 33

Characterizing household air quality in semi-rural Mozambique using a low-cost sensor

Author: JOVITO NUNES[None]

Co-authors: Ariadna Curto ; Cathryn Tonne ; Charfudin Sacoor ; Fabian Coloma ; Quique Bassat

Corresponding Author: jovito.nunes@isglobal.org

Aim: Ambient and household air pollution (HAP) are major contributors to mortality and morbidity in Sub-Saharan Africa; however, PM2.5 exposure measurements in the region remain scarce. We aimed to characterize PM2.5 within households of women and infants participating in a birth cohort study in Manhiça district, Southern Mozambique.

Methods: We measured time-resolved PM2.5 for up to two 5-day sessions in the main living area and kitchen using the HAPEX v4 low-cost data logger. HAPEX uses a light scattering sensor, has a 5-year battery life, and is designed for HAP monitoring. On-site correction factors were derived from UPAS, a filter-based micro pump sampler, placed □20 cm away from the HAPEX. HAPEX-UPAS co-location was 24 hours. We measured ambient PM2.5 using a BAM 1022, a reference-grade monitor.
Results: Between 3rd March and 30th of November 2022 135 households were sampled; 119 had a second measurement. Among sampled households, 72% had outdoor kitchens; 94% used solid fuel, 5% liquid fuel, and 4% electricity for cooking. Mean (SD) ambient PM2.5 was 14.95 μg/m3 (12.56) for dry season and 8.15 μg/m3 (8.15) for wet season. Mean (SD) 5-day average PM2.5 measured by

HAPEX in the living room was 27.43 µg/m3 (32.80) for dry season and 28.35 µg/m3 (66.00) for wet season.

Conclusions: Indoor PM2.5 concentrations in the main living area were considerably higher than ambient levels, indicating the influence of indoor sources. Measurements will be used to estimate long-term exposure to PM2.5 for application in epidemiological studies.

Panel Discussion / 35

A four year exposure assessment of ambient PM2.5 Concentration in Kampala, Uganda: Experiences from The Eastern Africa GEOHealth Hub

Author: Samuel Etajak[None]

Co-authors: Abera Kumie [1]; Agnes Nyabigambo [2]; Felix Walyawula [2]; Heather Wipfli [3]; Jonathan M. Samet [4]; Kiros T. Berhane [5]; Lynn Atuyambe [2]; Simon Kasasa [2]; William Bazeyo [2]

[1] *Addis Ababa University*

[2] *Makerere University School of Public Health*

[3] *University of Southern California*

[4] *University of Colorado*

[5] *Columbia University*

Corresponding Author: setajak@musph.ac.ug

Introduction
Air pollution (AP) remains a major a major environmental risk to the public health. Worldwide, 3.7 million deaths occur every year as a result of exposure to ambient air pollution. In Africa, AP is the 2nd largest death threat, causes more deaths than tobacco, alcohol, road accidents, and drug abuse. Sources of AP: traffic, especially in urban areas where traffic is a threat to PH (Samet 2001); biomass fuel burning; Industrial process. We prospectively monitored the PM2.5 levels in Kampala city and examined the daily and seasonal trends of PM2.5.

Materials and Methods
A time series design, we prospectively monitored daily ambient AP (PM2.5) concentration levels in micrograms per cubic meter (µg/m3). The study site was Kampala Capital City, Uganda. The PM2.5 sampling site is located at the Makerere University School of Public Health premise, Mulago National Referral Hospital. The study used data for the period 1st January 2018 to 31st December 2021.

Results
The annual PM2.5 Concentration for 4 years (2018-2021) was 39.3 µg/m3, 34.9 µg/m3 , 37.4 µg/m3 & 42.0 µg/m3 respectively. December, January, and February stand out with the highest concentration above 80µg/m3 . The 4 years of monitoring AP in Kampala shows that PM2.5 concentrations were above the WHO annual interim target 1 of 35 µg/m3

Conclusion
The findings show that air pollution in Kampala is way above the WHO Air Quality Guideline values, thus this situation poses an increased risk for adverse health effects including deaths attributed to air pollution

Poster Session / 36

Spatial Distribution of Respirable Particulates and Toxic Heavy Metal Pollutants in Nairobi CBD Area Ambient Air: Identifica-

tion and Quantification of Pollutant Sources Impacting on the Air Quality

Author: Margaret Gitau[1]

Co-authors: John Birir [2]; Michael Mangala [2]

[1] *MSc student- Nuclear Science and Technology*

[2] *Lecturer- University of Nairobi*

Corresponding Author: margaretrugurugitau@gmail.com

Air pollution has become a worldwide concern threatening public health and sustainable developments goals (SDGs). The Global Burden of Diseases GBD 2015 (GBD Risk Factors Collaborators 2016) classified respiratory particles as the fifth risk factor for causing death around the globe. The increase in population, industrial activities, vehicular emission and traffic, growth of construction buildings and roads, and waste burning, have contributed extensively to air pollution in most cities in SSA.
This study assesses the variation of respirable PM2.5 concentration levels and heavy metals pollutants in aerosols samples collected within Nairobi Central Business District (CBD), measured to determine sources impacting on ambient air quality.
Five selected sites within CBD were sampled concurrently for air quality parameters; particulates and meteorological data for 10-12 hours daily, for two months. 55 air particulate filter samples were sampled using personal cyclone samplers and analyzed for particulate mass concentrations and toxic heavy metal pollutants using EDXRF method.
The elemental data will be statistically analyzed using Positive Matrix Factorization method for pollutants source identification and quantification impacting on air quality.
The PM concentrations ranged from 15.38μg/m3 to 180.76μg/m3. The elemental concentrations varied significantly. Ca, Mn, Fe, Ni, Cu, Zn, Sr, Zr, Nb and Pb, were major pollutants contributors of air pollution to ambient air.
The study is relevant in air quality management, to understand the risks of poor air quality and mechanisms responsible for it, and to pin-point probable technological outcomes that would aid in mitigation in Nairobi CBD.
Key-Words- Air pollution, (SDGs), particulate matter, SSA.

Panel Discussion / **37**

Combination of Ground-based Measurements and Model Data to Improve Air Quality Estimations in Nairobi, Kenya

Author: Ezekiel Waiguru Nyaga[1]

Co-authors: Albert Presto [2]; Daniel Westervelt [3]; Emilia Tjernstrom [4]; Godwin Opinde [5]; John Mungai [6]; Matthias Beekmann [7]; Michael J. Gatari [8]; Moses Njeru [8]; R. Subramanian [9]; Savannah Ward [3]; Tedy Mwendwa [5]; V. Faye McNeill [10]

[1] *Laboratoire Interuniversitaire des Systèmes Atmosphèriques (LISA), UMR CNRS 7583, Universitè Paris Est Crèteil et Universitè de Paris, Institut Pierre Simon Laplace, Crèteil, France*

[2] *Carnegie Mellon University, Pittsburgh*

[3] *Lamont Doherty Earth Observation of Columbia University*

[4] *School of Economics, University of Sydney*

[5] *Kenyatta University Department of Environmental Planning and Management*

[6] *Innovations for Poverty Action (IPA), Nairobi, Kenya*

[7] *Laboratoire Interuniversitaire des Systèmes Atmosphèriques (LISA), UMR CNRS 7583, Universitè Paris Est Crèteil et Universitè de Paris, Institut Pierre Simon Laplace, Crèteil, France; OSU-Efluve, Observatoire Sciences de l'Univers-Enveloppes Fluides de la Ville à l'Exobiologie, Université Paris-Est-Créteil, CNRS UMS 3563, Ecole Nationale des Ponts et Chaussés, Université de Paris, France*

[8] *University of Nairobi Institute of Nuclear Science and Technology*

[9] *Laboratoire Interuniversitaire des Systèmes Atmosphèriques (LISA), UMR CNRS 7583, Universitè Paris Est Crèteil et Universitè de Paris, Institut Pierre Simon Laplace, Crèteil, France; OSU-Efluve, Observatoire Sciences de l'Univers-Enveloppes Fluides de la Ville à l'Exobiologie, Université Paris-Est-Créteil, CNRS UMS 3563, Ecole Nationale des Ponts et Chaussés, Université de Paris, France; Kigali Collaborative research Centre, Rwanda*

[10] *Columbia University Department of Chemical Engineering*

Corresponding Author: ezekielwaiguru24@gmail.com

The rapid population growth coupled with urbanization has caused increase in human activities leading to degradation of air quality in Nairobi. Exposure to air pollution is a leading risk factor associated with premature deaths. The air monitoring campaign conducted in the context of MOPGA (Make Our Planet Great Again) project provided two-year (2020-2021) measurements of PM2.5 and NO2 compounds in Nairobi using Clarity-Node sensors. Six sensors were collocated side-by-side with a BAM-1020 reference-grade monitor (January-April 2021) at the University of Nairobi in order to derive PM2.5 correction factors. Simple linear regression model was used to normalize NO2 data against one low-cost sensor due to lack of a reference instrument. The corrected daily average PM2.5 mass concentrations were largest at KUCC (27.6 µg/⊠3) urban roadside site, then BuruBuru (26.4 µg/⊠3) and Marurui (26.3 µg/⊠3) residential sites, followed by UoN (21.7 µg/⊠3) and IPA (20.3 µg/⊠3) urban background sites, and the least was Ngong (17.8 µg/⊠3) peri-urban site. Furthermore, high PM2.5 values were observed at low wind speeds (< 4 m/s) pointing to local pollution sources. The normalized NO2 measurements showed variabilities in different locations with the highest concentrations (25.6 ppb) at KUCC traffic dominated site and the least (14.4 ppb) at Ngong. PM2.5 diurnal pattern mimicked daily traffic cycle with constantly higher evening peaks compared to morning peaks indicating residential emissions. We are also modeling air quality across East Africa using CHIMERE, which will be combined with the sensor measurements to better understand local and regional sources of air pollution in Nairobi.

Poster Session / 38

Low-cost source attribution of PM2.5 in Kinshasa, Democratic Republic of the Congo

Author: Daniel Westervelt[1]

Co-authors: Garima Raheja [2]; Paulson Kasereka [3]; Rodriguez Yombo Phaka [4]

[1] *Columbia University*

[2] *Columbia University in the City of New York*

[3] *ERAIFT, DRC*

[4] *RDC (Kinshasa)/Liège*

Corresponding Author: danielmw@ldeo.columbia.edu

Estimates of air pollution mortality in sub-Saharan Africa are limited by a lack of surface observations of fine particulate matter (PM2.5). Despite being a large metropolis, Kinshasa, Democratic Republic of the Congo (DRC), population 14.3 million, has had little attention towards air quality monitoring. In 2019, a 5-node PurpleAir network was deployed in the city. Calibrated annual average PM2.5 for 2019 in Kinshasa was estimated at 43.5 µg m-3, more than 8 times higher than WHO Interim Target 1 of 5 µg m-3. This initial study motivated additional instrumentation in Kinshasa, the whole Congo and neighboring Brazzaville. New deployments included a small Clarity Node-S network, a QuantAQ Modulair, and a reference method PM2.5 MetOne Beta Attenuation Monitor (BAM-1020). In addition, monitoring of gas-phase species, including NO2, O3, CO, CO2 is now underway. Here we present first results from this aggregated, multi-sensor, multi-species network in the Congo. We first conduct a sensor intercomparison, comparing the performance of three different popular sensor brands (PurpleAir, Clarity, and QuantAQ) evaluated against the reference BAM-1020. Initial findings suggest that QuantAQ PM2.5 is most correlated and least biased compared to the reference, followed by PurpleAir and by Clarity. We also use our co-location to develop a simple correction factor using both Multiple Linear Regression and Gaussian Mixture Regression, a probabilistic method that has been shown to perform better than commonly used methods in other African cities. We also leverage on-site gaseous pollutant concentrations, particle size distribution

data from an optical particle counter, and anemometer data to draw some initial conclusions about sources of PM2.5 in Kinshasa. In particular, we link factors resolved from a nonnegative matrix factorization method using the gaseous species and particle bin concentrations to particular source profiles (e.g. combustion). Our results highlight the need for clean air solutions implementation in the Congo.

Poster Session / 39

ASSESSMENT OF ORGANOPHOSPHATE FLAME RETARDANTS IN AIR SAMPLES FROM AN ELECTRONIC WASTE DUMPSITE IN LAGOS, NIGERIA

Author: Temilola Oluseyi (Ph.D)[1]

Co-authors: Aderonke Oyeyiola [1]; Mohamed Abdallah [2]; Moyofoluwa Ogunyemi [1]; Stuart Harrad [2]

[1] *Department of Chemistry, University of Lagos, Nigeria*

[2] *School of Geography, Earth & Environmental Sciences, University of Birmingham, Birmingham B15 2TT UK*

Corresponding Author: toluseyi@unilag.edu.ng

In developing countries, recycling of electrical and electronic waste (e-waste) has attracted much attention as a significant source of persistent organic pollutants (POPs). E-waste contains hazardous materials such as flame retardants (FRs) that require special handling and recycling methods to avoid environmental contamination and detrimental effects on human health. E-waste dumpsites have been found to contain a composite of these wastes, which are released to the surrounding environments –air, water, dust, soil and sediment during improper recycling activities such as the manual dismantling of devices and open burning of e-waste. When e-wastes are improperly dismantled and recycled, toxic pollutants are released into the environment.
Human exposure to e-waste is on the increase in Nigeria. This is because of the indiscriminate disposal and crude informal recycling methods in the country. This study reports for the first time the occurrence of Organophosphate Flame Retardants (OPFRs) in atmospheric samples from an e-waste dumpsite in Lagos, Nigeria. In this study, ten indoor and outdoor air samples were collected between June and July 2022 from five different locations at an e-waste dumpsite in Lagos, Nigeria, to investigate the occurrence of a range of 7 congeners of OPFRs which include tris (2-chloroethyl) phosphate (TCEP), tris (2-chloroisopropyl) phosphate (TCIPP), tris (1,3-dichloro-2-propyl) phosphate (TDCIPP), amongst others. Overall, the highest mean concentration of OPFRs was found in the indoor repair and storage shop (12,770 pg/m3); followed by the indoor dismantling shop (10,505 pg/m3). TCIPP had the highest mean concentration for all samples (15,230 pg/m3), followed by TCEP (15,040 pg/m3) while the least was EHDPP (257 pg/m3). All target compounds were detected at the dumpsite; the concentrations from outdoor samples were comparatively lower than the indoor air samples indicating a health risk to the e-waste workers who spend a large proportion of their time indoors sorting the e-waste and have high exposure to hazardous air pollutants.

Poster Session / 41

Statistical Trends and Characterization of Atmospheric Pollutants Levels Using Low-Cost and Satellite Total Column Data in the Greater Accra Metropolitan Assembly (GAMA), Ghana

Author: James Nimo[1]

Co-authors: Azoda Koffi [1]; Alabi Omowumi [2]; Benjamin Essien [3]; Emmanuel K.-E Appoh [3]; Ramachandran Subramanian [4]; Nana Ama Browne Klutse [1]; Allison Hughes [1]

[1] *Department of Physics, University of Ghana, Legon*

[2] *African Regional Centre for Space Science and Technology Education in English, Ile-Efe, Nigeria*

[3] *Ghana Environmental Protection Agency, Accra, Ghana*

[4] *Kigali Collaborative Research Centre, Kigali, Rwanda*

Corresponding Author: jnimo@st.ug.edu.gh

In this study, long-term trends over 5 Ghana EPA traffic stations on (25 x 25) km resolution satellite OMI instrument and (50 x 50) km resolution MODIS Terra AOD from 2012 to 2021 were assessed using Mann-Kendall test to ascertain the impact of population growth coupled with increasing sources for the past decade in the GAMA. Further, characterization of Clarity Node-S PM2.5, AOD, NO2, and O3 levels in the GAMA was assessed while the Pearson coefficient was used to find correlations between the pollutants. Overall, there was an increasing trend in NO2 ($p < 0.05$), no trend in O3 ($p > 0.05$) and a decreasing trend in AOD ($p < 0.01$). Pearson coefficients between PM2.5 data and MODIS Terra AOD were (R2 = 0.72, 0.72, 0.67, 0.58 and 0.57) respectively. Correlation coefficient between column NO2 and O3 was (R2 = -0.83 ± 0.030, $p < 0.01$), AOD and O3 (R2 = -0.43 ± 0.003, $p < 0.01$), NO2 and AOD (R2 = 0.21 ± 0.010, $p > 0.01$). PM2.5, AOD and NO2 levels were high generally during the dry season while high concentrations of O3 were observed in the wet season across the stations. Again, an increasing and decreasing trends in NO2 and AOD levels show that sources of poor air quality may be shifting from the usual biomass burning to traffic emissions. High population growth with increasing traffic in growing sub-Saharan African cities requires urgent policy measures and regulations as ground air quality monitoring sensors are limited.

Panel Discussion / **42**

AIR QUALITY MONITORING IN AFRICA: MY NIGERIA ANGLE

Author: Rose Alani[None]

Corresponding Author: rosealanito@gmail.com

My air quality monitoring activities in Nigeria involves passive, active and real-time monitoring from 2015 to date, with much attention being paid to Lagos megacity. The choice of Lagos State is necessitated by the concentration of commercial, industrial, and educational activities, consequently resulting in urbanization, overpopulation, and traffic congestion. Lagos State accounts for about 30% of all traffic in Nigeria, which is a big challenge given the limited road infrastructure and development. Also, 70% of Nigeria's industrial and commercial activities are in the Lagos region, making it the commercial nerve center and the most populous state in the country. The population of Lagos city is increasing ten times faster than New York and Los Angeles.
One of my passive air monitoring activities in Lagos is the pilot study initiated in 2018 under the Global Atmospheric Passive Sampling (GAPS) Network named GAPS-Megacities. This study included 20 megacities/major cities across the globe with the goal of better understanding and comparing ambient air levels of persistent organic pollutants and other chemicals of emerging concern, to which humans residing in large cities are exposed.
One of my active air monitoring activities in Lagos evaluated the PM2.5 concentrations and its bound elements in Agege, Oshodi, and Unilag, Lagos, Nigeria. Aerosol samples were captured on a microglass fiber particle filter and the PM2.5 determined gravimetrically. Elemental characterizations of PM2.5 were performed by energy dispersive X-ray fluorescence. The PM2.5 concentrations ranged from 6 to 14 µg/m3 in Unilag and Agege respectively. The PM2.5 was lower than the WHO regulatory standard (25 µg/m3). This could be attributed to high precipitation during the sampling. All the 19 elements determined in the samples were found in the locations except arsenic which was not found in any of the samples.
In one of my realtime monitoring activities we used multi-temporal and multi-spectral Landsat imageries at four epochs (2002, 2013, 2015, and 2020) to evaluate the aerosol optical thickness (AOT) levels in relation to land cover and road networks in the Lagos megacity. A comparative assessment of the method against in situ measurements of particulate matters (PMs) at three different locations shows a strong positive correlation between the imagery-derived AOT values and the PMs. The AOT concentration across the land cover and road networks showed an increasing trend from 2002 to 2020, which could be explained by urbanization in the megacity.

With World Bank Pollution Management and Environmental Health (PMEH) group, our study produced the report on the "Cost of Air Pollution in Lagos"which showed that Exposure to ambient PM2.5 has significant health impacts in Lagos, costing society about US$2.1 billion, or Naira 631 billion28 in 2018.
There are a lot more studies on air quality in Nigeria but most of them are presently concentrated in Lagos, though we are gradually extending to other states.

Keyword: Air quality, Passive monitoring, Active monitoring, Realtime monitoring, Lagos, Nigeria

Poster Session / 43

Temporal variability of Black Carbon in Kigali

Author: olivier kundwa[None]

Co-author: jean de dieu Ndayisenga

Corresponding Author: kundwa52@hotmail.com

Kigali, the capital city of Rwanda, is characterized by an increasing population and a rising rate of transport facilities. African countries, including Rwanda, are concerned with the air pollution problem. Different pollutants produced by burning wood for cooking and household chores, cookstoves, generators and engines with substandard fuel use and others, could be detected. This study provides the daily data of BC at UR-CST, Nyarugenge campus site, during different seasons continuously for the period from September 2019 up to July 2020 and different conditions with a special emphasis on the COVID-19 Lockdown period, using a Magee Scientific 7-wavelength Aethalometer® Model AE33-7. Different trends were done and analyzed. The seasonal variation of BC showed that the September-October-November (SON) and March-April-May (MAM) seasons had the lowest mean concentration of 4.130410 µg/m3 and 3.493238 µg/m3 respectively. This is explained in the first place by the fact that the wet removal is believed to be the primary removal of BC in the atmosphere, and secondly by the COVID-19 lockdown period that reduced many activities in Kigali. On the other hand, December-January-February (DJF) season presents higher BC concentration with a mean of 5.665593 µg/m3 followed by the months of June-July with an average of 5.613771 µg/m3. The data for August were missing, but previous studies indicate that the Long dry season (JJA) presents the highest BC concentration compared to other seasons as it has been proven that there is a positive correlation of BC with temperature, and the JJA season presents the highest average annual temperature. The weekdays, weekends and hours of the day's differences in BC concentrations showed that BC concentrations follow a daytime pattern with peaks in the morning because of traffic density and late afternoon in hours of leaving offices and late in the evening during cooking hours with less pollution found in office hours. The study also found an overall pollution during weekdays and less pollution in weekends which is explained by less activities in weekends that generates BC. The study also shows that nighttime presents higher BC concentrations compared to daytime and that BC pollution can be globally transported.

Poster Session / 44

Study of the Performance of a Regional Climate Model in Simulating Rainfall in Rwanda

Author: Alexis Bazambanza[None]

Corresponding Author: bazalexis40@gmail.com

High resolution models were used for simulating rainfall in Rwanda. But each model should be evaluated before using its output to assess impact. The ability of Regional climate model (RCM) was evaluated using RegCM4-7 which is driven by the MPI-M-MPI-ESM-LR to simulate rainfall over Rwanda. The model output was compared to observation to simulate rainfall in Rwanda through assessing the model performance. Bias, root mean square error (RMSE) and Pearson correlation

were used to assess model skill while Mann-Kendall (MK) was used for trends analysis.
It is found that model performance in simulating rainfall both seasons over Rwanda, overestimates rainfall in October-November-December (OND) season over all part of country with positive biases but much more to north and South-West and Underestimates in March-April –May (MAM) season over the Central and Eastern part of Country with Negative biases and model simulates rainfall over the country better with less errors in MAM than OND season.
The future projection of rainfall with two scenarios RCP2.6 and RCP8.5 for near future period (2021-2050) and far future period (2051-2080) for 30 years were used and they show that the average rainfall will increase in western and Southern party of the country while a greater changes projected during OND and less in MAM under both scenarios and Periods.
Overall, the study finds that RCM used is able to simulate rainfall climatology in Rwanda with better performance and suggesting the potential use of in further similar studies.

Panel Discussion / **45**

Breathe Accra Project

Author: Kofi A. Amegah[None]

Corresponding Author: aamegah@ucc.edu.gh

Accra City authorities have been very slow in addressing the air quality challenges in the city in spite of having an Air Quality Management Plan (AQMP) developed by the Ghana Environmental Protection Agency (EPA) in 2018. The reasons are lack of reliable data on air pollution levels due to limited air quality monitoring capacity; absence of local evidence on the human health impact of air pollution exposure, and the magnitude of the associated health risk; and lack of capacity at the assemblies for implementing the AQMP.The municipal and sub-metropolitan authorities in Accra have no involvement in the monitoring programme of Ghana EPA. This is in spite of municipal assemblies having departments of development planning, physical planning, and environmental health and can be leverage to improve air quality in the city in their respective districts. It is against this background that the Breathe Accra project is being implemented to ensure openly accessible hyperlocal air quality data in the Greater Accra Metropolitan Area, and to foster local capacity for monitoring and managing air quality, and mounting surveillance for air pollution-related diseases in the Great Accra Metropolitan Area. The project also hopes to share technical details, best practices and lessons learnt on the project for replication by other African cities. This presentation will detail the project implementation plan, activities, and the expected outcomes and impact.

Poster Session / **46**

Investigating the Concentration and Sources of Black Aerosols at an Urban Site in North Africa: A Study of Kenitra, Morocco

Author: Youssef BOUNAKHLA[None]

Co-authors: Abdelfettah BENCHRIF [1]; El Hassan El Kafssaoui [2]; Fatiha Zahry [1]; Mounia Tahri [1]; Moussa Bounakhla [1]

[1] *National Centre for Nuclear Energy, Science and Technology (CNESTEN), Morocco*

[2] *Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco*

Corresponding Author: youssef.bounakhla@uit.ac.ma

In this study, data collected from a seven-wavelength aethalometer was used to investigate the levels and patterns of equivalent black carbon mass concentrations in Kenitra, Morocco, a city in North Africa between mid-July 2020 and mid-February 2021. The average concentration of black carbon (BC) was found to be 0.90 ± 0.80 µg/m3, which is lower than the levels typically seen in African and European cities. This lower value may be due to the influence of COVID-19 restrictions. The BC concentrations showed a bimodal pattern throughout the year, with the magnitude of the peaks varying

by season. This seasonal variation was linked to changing meteorological conditions and the height and pathways of air masses. During the weekdays, BC concentrations were higher during the day than at night, while slight increases in BC were observed at night on the weekends. Local sources, such as road traffic, were found to be significant contributors to BC concentrations. However, backward trajectories also showed that long-range aerosols from strong maritime activity in the Atlantic region and polluted air masses from populated areas to the west could also contribute to BC concentrations. Overall, BC concentrations typically did not exceed 0.5 µg/m3, which is considered an "urban background level.

Poster Session / 47

Diesel powered vehicle fleet Carbon Monoxide (CO), Nitrogen monoxide (NO) and Carbon dioxide(CO2) emission factors in Rwanda.

Author: THEOBARD HABINEZA [1]

Co-author: Presto Albert [2]

[1] *CARNEGIE MELLON UNIVERSITY*

[2] *CMU*

Corresponding Author: htheobar@andrew.cmu.edu

strong text
Exhaust emissions from road traffic are considered as major contributors to urban air pollution. Diesel powered vehicle emissions are classified as the main source of traffic emissions that count for a higher emission percentage (40% of total emissions in Kigali) in different cities. In addition to different air pollutants from diesel vehicles'exhaust that act as precursors to the ozone formation, diesel engines emits Carbone dioxide (CO2) which is a greenhouse gas contributing to the global warming and Black Carbon(BC) which is a major contributor of the diesel particulate matter. The age of vehicle fleet, maintenance and driving condition play a big role in determining the emission factor of the vehicle fleet. On road Mobile emissions tester (E-6500, E-8500, and E-900) were used to collected vehicle emission data from 55 diesel powered vehicles'exhaust in five different provinces (Kigali city, Western province, Eastern Province, southern province and North Province) of Rwanda in 2022. The so called, very old vehicles fleet (manufactured before 2004) recorded higher carbon monoxide (CO) and nitrogen oxide (NO) emission factors compared to new vehicle fleet (manufactured after 2015). CO and NO emission factors increased with the fleet age whereas CO2 emission factor decreased with the vehicle fleet age. CO/CO2 ratio reduced considerably from new vehicle fleets to old and very old vehicle fleets respectively. This was a good indicator that most of the old and very old vehicle fleets run under fuel rich condition whereas new vehicle fleets run under fuel lean condition. This work also revealed that most vehicle fleet in Rwanda are more than 15 years old and their engines run under fuel rich conditions.

Poster Session / 48

Diurnal and Seasonal Variability of Ambient Ozone over Nyarugenge District in Kigali City

Author: Jean de Dieu Ndayisenga[None]

Corresponding Author: ndajadhon@gmail.com

The ambient ozone over Nyarugenge district in Kigali City varies seasonally, the study analyzes the near surface ambient ozone within a period of three years starting from 2010 to 2012 using openair model (R package) which is an open-source tools for analyzing air pollution data, and correlated with its corresponding meteorological parameters including air temperature, relative humidity, wind speed and wind direction. The highest ambient ozone concentration along a day was observed between 10am to 3pm, this is because its chemical formation is a photochemical reaction. For wind speed above 2.81m/s ambient ozone increases as solar radiation increase while for wind speed level greater than 2.81m/s the ambient ozone concentration decreases by increasing of atmospheric relative humidity. The average wind speed recorded was at 3.7402 m/s with calm condition of 0% during July to September 2020 and pollution rose of 22.85 from 17th to 23rd September 2020. The dominant wind direction was elaborated together with their frequency. During dry seasons the ambient ozone concentration in Kigali is very high compare to the wet seasons and this affect the nearby rural area (downwind), the major cause of this increase include the biomass burning, higher solar radiation intensity, contribution of transboundary pollutants and lower pollutants removal processes. For mitigating increase of ambient ozone and generally air pollutants there is a need to install lower cost air quality monitoring instruments in different zone across the country for its monitoring, mobilizing smart driving, the use of motorcycle and auto cycle which use electric power instead fuels as trafficking emission is among the main pollutants sources in Kigali, the use of air filter on chimney of the manufacturing industries and other technics for minimizing emission.

Poster Session / 49

Spatio-temporal variability of PM2.5 in the West African cities of Abidjan and Accra

Author: Julien BAHINO[1]

Co-authors: Arsène OCHOU [1]; Corinne GALY-LACAUX [2]; Matthias Beekmann [3]; Michael R. Giordano [4]; R. SUBRAMANIAN [5]; Véronique YOBOUE [1]

[1] *Université Félix HOUPHOUET-BOIGNY*

[2] *Laboratoire d'Aerologie*

[3] *OSU-Efluve, Univ Paris Est Créteil, Ecole des Ponts Paris Tech*

[4] *Kigali collaborative Research Centre*

[5] *Univ Paris Est Créteil and Université de Paris*

Corresponding Author: bahinojulien@gmail.com

Populations living in West African capitals are increasingly exposed to fine particles from anthropogenic activities. However, the high cost of reference measurement instruments makes it difficult to conduct studies to routinely assess exposure levels and impacts. Particulate Matter (PM) Low-Cost Sensors are widely used to monitor air quality in regions where no reference monitors are available. This study carried out within the framework of the Improving Air Quality in West Africa (IAQWA) project funded by the Make Our Planet Great Again (MOPGA) program aims to provide high quality data on fine PM2.5 mass concentrations in Abidjan (Cote d'Ivoire) and Accra (Ghana) through the deployment of Real-time Affordable Multi-pollutant (RAMP) monitors. RAMPs were co-located with reference monitors to create specific localized PM2.5 calibration models for the two West African cities. From February 2020 to June 2021, RAMPs units were deployed at five sites in Abidjan and four sites in Accra. The corrected data set of hourly data allows, for the first time, for the comparison of the diurnal, daily and seasonal variability of PM2.5 concentrations for different urban sites with distinct pollution sources, over an extended period of time. The PM2.5 diurnal variation at these sites is related to different pollution sources such as traffic and residential activities. Based on analysis of satellite data of aerosol optical thickness (AOD), peak PM2.5 concentrations measured in Abidjan and Accra were related to regional scale dust transport. Finally, we determined the annual averages of PM2.5 at all sites and compared them to available observations over Western Africa and to WHO standards.

Poster Session / 50

Indoor Aerosol Exposure in Akure Metropolis, Nigeria

Author: Francis Olawale Abulude[1]

Co-authors: Adedeji A. Adelodun [2]; Prashant Kumar [3]; Sarkawt Hama [4]

[1] *Science and Education Development Institute, Akure, Ondo State, Nigeria*

[2] *Department of Marine Science and Technology, The Federal University of Technology Akure, 340001, Nigeria*

[3] *Global Centre for Clean Air Research (GCARE), School of Sustainability, Civil and Environmental Engineering, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, GU2 7XH, Surrey, United Kingdom*

[4] *Global Centre for Clean Air Research (GCARE), School of Sustainability, Civil and Environmental Engineering, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, GU2 7XH, Surrey, United Kingdom*

Corresponding Author: walefut@gmail.com

Air pollution is a major threat to public health. By reducing environmental impacts, countries can reduce the burden of illnesses such as stroke, heart disease, lung cancer, and chronic or acute respiratory diseases (such as asthma). This study assessed indoor aerosol exposure in the Akure metropolis (residential, office, commercial area, and laboratories). The profiles of average PM10 and PM2.5 levels indoors were higher than 15 (annual) and 45 µg/m3 (24 h) (PM10) and 5 (annual) and 15 (24 h) (PM2.5) respectively of the WHO air quality guidelines for 2021. CO2 levels in all locations were lower than the WHO guideline (1000 ppm). The mean PM2.5/PM10 ratios observed in all the rooms were 0.23 –0.56 with the overall values, ranged 0.12 –1.00. Pollutants, temperature, and relative humidity showed weak relationships. In addition, the toxicity potential of the pollutants was less than one. In most study areas, the mean AQI for PM10 and PM2.5 (annual) range between good and moderate. Similarly, the mean AQI for PM10 and PM2.5 was either good or moderate (24 h). The highest indoor AQI levels were unhealthy and dangerous. The Hazard ratio (HR) for PM2.5, PM10, and CO2 were less than one in most locations. HRs <1 exposure levels are unlikely to cause any negative health effects. Although the monitored environments are unlikely to pose any threat, efforts should be directed toward constant monitoring, mitigation, and adequate indoor ventilation.

Poster Session / 51

Spatio-temporal trends of air quality in Kampala City, 2020–2022

Author: Mackline Ninsiima[1]

[1] *Kampala Capital City Authority and Uganda Public Health Fellowship Program - TEPHINET*

Corresponding Author: nmackline@musph.ac.ug

Background: Fine particulate matter (PM2.5) has been recommended as the best measure of air quality. We assessed the spatio-temporal trends of air quality based on PM2.5 concentrations in Kampala City.

Methods: PM2.5 concentrations generated by 25 Clarity Node Solar-Powered monitors from January 1, 2020–June 30, 2022 were abstracted from the Clarity dashboard. We computed 24-hour average PM2.5 concentration at city and division levels. Average PM2.5 concentrations were compared by hour of the day to understand the variations in air quality throughout the day. Seasonal Mann-Kendall statistical test was applied to assess the trend of 24-hour average PM2.5 concentrations.

Results: Overall, the 24-hour average PM2.5 from January 1, 2020–June 30, 2022 was 59 µg/m3 (range: 18–182 µg/m3) in Kampala City. High PM2.5 concentrations were observed in all divisions of the city: Kawempe (63 µg/m3), Central (61 µg/m3), Rubaga (60 µg/m3), Nakawa (55 µg/m3) and Makindye (52.7 µg/m3). Two PM2.5 concentration peaks were observed from 10am–midday (73.2–72.9 µg/m3) and 8pm–9pm (73.3–77 µg/m3). There was a negligible but significant decreasing trend from January 2020 to June 2022 ($r = -0.27$, $p < 0.001$). PM2.5 increased during April–June throughout all evaluation years [2020 (r=0.56, p=0.006), 2021 (r=0.26, p=0.030), and 2022 (r=0.37, p=0.030)]. Significant decreasing trends were observed during July–September, 2021 (r=-0.43, p=0.008) and January–March, 2022 (r=-0.41, p=0.011).

Conclusion: Unhealthy air quality evidenced by PM2.5 concentrations exceeding the WHO targeted "safe"level was observed even during times of less traffic and economic activities in Kampala City.

Poster Session / **52**

Observing and source signatures across Dakar, Senegal

Author: Aissatou Faye[1]

[1] *Department of Environmental Sciences, University of Virginia (UVA)*

Corresponding Author: aichafaye8@gmail.com

Nitrogen dioxide (NO2) is an urban air pollutant produced by combustion processes and can be detrimental to health and the environment at global and regional scales. However, their impact is still unknown because of the lack of air monitoring, especially in poor countries like West Africa.
The main objective of this work was to assess NO2 air pollution variability in Dakar, Senegal. First, we presented data from a measurement campaign from February- March 2020. Results show that NO2 values are higher in most parts of Dakar, especially in higher traffic congestion, human activities, and bus terminals for local and traditional buses. Secondly, we have used these monitored data to train a high spatial resolution linear machine learning model (LASSO). The model was able to have a generally good spatial distribution with hotspots of NO2. In the last part, we will represent some results from a new measurement campaign done in early 2023 for collecting a wider variety of combustion pollutants including NO, NO2, CO, CO2, O3, and SO2 across Dakar. We will use these observations to map trace gas enhancement ratios, which inform the types of combustion pollutants, not just their distributions in both Dakar city and the rural zone. We will also discuss air pollution monitoring networks using low-cost sensors over the entire Senegal.

Poster Session / **53**

TEMPO-Africa: Enhanced Air Quality Measurements from Space

Author: Jordan Marks[1]

Co-author: Sheldon Drobot [1]

[1] *Ball Aerospace*

Corresponding Author: jordan.marks@ballaerospace.com

Poor air quality is now one of the three main causes of premature morbidity, resulting in nearly 7 million deaths globally in 2022. Moreover, 99% of the world's population experiences air pollution levels exceeding World Health Organization guidelines, and fatalities in Africa from outdoor air pollution have increased nearly 60% in the last 30 years. Yet, our ability to mitigate poor air quality and the damage it causes is hampered by a lack of actionable information.
Fortunately, things are beginning to change. The Geostationary Environment Monitoring Spectrometer (GEMS), built for South Korea and launched in 2020, is the first in a new generation of satellites observing air pollution every daylight hour with around a 5-kilometre resolution. GEMS operates over the Korean peninsula and the broader Asia-Pacific region, and it is helping scientists to pinpoint more accurately what the pollutants are, where they are coming from, and to get a precise idea of where they are moving. Launching later in 2023, the Tropospheric Emissions: Monitoring Pollution (TEMPO), will do a similar job over North America, with slightly better spatial resolution. With that kind of information, governments, local authorities and businesses are better equipped to identify concerning areas and to make informed decisions about what action to take. Non-governmental organizations and the wider civil society can also use the information to hold governments and industries accountable for the quality of air we breathe.

In this presentation we'll outline a TEMPO-Africa concept and look to find partners to turn this vision into reality.

Poster Session / 54

Exploring the robustness of air sensors for understanding the impacts of location-specific agricultural practices on local air quality.

Authors: Anthony Amoah[1]; Anthony Kporsu[2]; Chris Hagerbaumer[3]; Colleen Marciel F. Rosales[4]; Collins Gameli Hodoli[1]; Daniel Dzorkpe Gamenyah[5]; Daniel Westervelt[6]; Emmanuel Appoh[7]; Felix Alison Hughes[8]; Frederic Coulon[9]; Iq Mead[10]; James Nimoo[8]; Katie Moore[11]; Mike Giordano[12]; Nelson Kowu[13]; Sean Wihera[11]; Stephen Yeboah[5]

[1] *University of Environment and Sustainable Development and Clean Air One Atmosphere*

[2] *Clean Air One Atmosphere*

[3] *OpenAQ*

[4] *Air Quality Research Center, University of California in Davis and OpenAQ, USA*

[5] *Council for Industrial and Scientific Research, Ghana*

[6] *Columbia University*

[7] *Ghana EPA*

[8] *University of Ghana*

[9] *Cranfield University*

[10] *Imperial College*

[11] *Clarity Movement*

[12] *AfriqAir*

[13] *Dept of Earth and Environmental Sciences, University of West Florida, Pensacola, FL, USA*

Corresponding Author: cghodoli@uesd.edu.gh

A significant number of studies have demonstrated the link between agriculture and air pollution. These studies have echoed that in most parts of Africa, the slash-and-burn approaches used for farming are responsible for local and regional air pollution as well as reduced food production. In these environments, however, sporadic air quality monitoring hinders understanding and quantifying the damage's degree. The lack of monitoring is firstly linked to the cost associated with procuring and operating conventional air quality monitors on the order of $100,000s but is also tied to limited local expertise and logistics. Additionally, identifying the impacts of agricultural practices on air pollution requires knowledge of baseline pollution. Specifically for rural Africa, baseline levels of air pollution are not known. This study explores the robustness of Clarity Node-S, a multi-sensor node to understand their functionality in varying agroecological settings in Ghana to support local air quality campaigns. Four Clarity Node-S were firstly calibrated at the University of Ghana, Accra using the multiple linear regression model with ˜4-week data from the Clarity Node-S and reference-grade Teledyne PM mass monitor T640 for PM2.5. We observed a high similarity between the four air sensors though hourly PM2.5 measurements were an over-estimation ranging 15 to 85 µg/m3. Calibrated PM2.5 values ranged from 2 to 38 µg/m3 higher than the WHO Air Quality Guidelines. The highest pollution trends were observed at Sokwai Community (SC) followed by Fumesua Community (FC), Fumesua Farm (FF) and Sokwai Farm (SF). Hourly episodes were recorded with levels ranging between 20 and 180 µg/m3 at the four agroecological settings. The highest, 180 µg/m3, was recorded at SC between 28th August and 1st September 2022. The lowest PM2.5 levels were recorded at the SF below 10 µg/m3. These preliminary results point to PM pollution at the community level but not at the farms in Kumasi, Ghana. The results presented here demonstrate the robustness of these miniaturised devices for establishing baseline levels of air pollution in agroecological settings in Ghana and similar environments typical of wider Africa.

Poster Session / 55

Hardware-Software Co-design of a Smart IoT Device for Monitoring Short-term Exposure to Air Pollution Peaks

Author: Eric Nizeyimana[1]

Co-author: Damien Hanyurwimfura [1]

[1] *University of Rwanda*

Corresponding Author: ihopegod@gmail.com

Air pollution spikes have been causing harm to human beings and the environment. Most exposure to Air pollution spikes has demonstrated a great impact on mental health, especially for children at an early age. That can lead to suicide or depression. Most existing research has been concentrated on air pollution in general. Existing monitoring systems are based on capturing the pollutants without being based on peaks. This paper presents the co-design of the hardware and software for IoT for monitoring spikes of air pollution. The system will be composed of two technologies such as edge computing to capture short-term exposure and machine learning for analyzing the captured data. This system will ensure the presence of the spikes start and end. The system will be able to alert the presence of spikes in air pollution. After the analysis, legislators will be based on smart contracts to reduce the peak of pollution based on its source.

Poster Session / 56

Multiyear observations of NO2 and SO2 vertical column measurements by PANDORA and TROPOMI in Dakar, Senegal

Author: Demba Ndao Niang[1]

Co-authors: Mamadou Simina Drame [2]; Angelique M. Dementillo [3]; Aissatou Faye [4]; Elena Spinei Lind [5]; Benjamin De Foy [6]; Thierno Doumbia [7]; Amadou Thierno GAYE [1]; Aminata Mbow Diokhane [8]; Robert J. Swap [5]; Nader Abuhassan [5]; Sally Pusede [3]

[1] *Laboratory of Atmospheric-Ocean Physics Simeon Fongang, Ecole Superieur Polytechnique de Dakar, Cheikh Anta Diop University, Dakar, Senegal (LPAOSF)*

[2] *Laboratory of Atmospheric-Ocean Physics Simeon Fongang, Ecole Superieur Polytechnique de Dakar, Cheikh Anta Diop University, Dakar, Senegal (LPAOSF); Department of Physics, Faculty of Science and Technology, Cheikh Anta Diop University, Dakar, Senegal;*

[3] *Department of Environmental Sciences, University of Virginia, Charlottesville, VA, USA*

[4] *Laboratory of Atmospheric-Ocean Physics Simeon Fongang, Ecole Superieur Polytechnique de Dakar, Cheikh Anta Diop University, Dakar, Senegal (LPAOSF), 4 Department of Environmental Sciences, University of Virginia, Charlottesville, VA, USA*

[5] *NASA Goddard Space Flight Center, Greenbelt, MD, USA*

[6] *Earth and Atmospheric Sciences, Saint Louis University*

[7] *Aerology laboratory of Toulouse, France*

[8] *Air Quality Management Center, Directorate of Environment and Classified Establishments, Ministry of Environment, Senegal*

Corresponding Author: niangdembandao@gmail.com

Nitrogen dioxide (NO2) and sulfur dioxide (SO2) are primary air pollutants and ozone and secondary aerosol precursors that are emitted by vehicles, ships, powerplants, industrial processes, and other combustion sources. There is a general lack of ground-based observational data in West African cities, which has limited our understanding of the sources, relationships with human activities, and meteorological controls over NO2 and SO2. Because of this, we installed a Pandora NO2 and SO2 spectrometer on the rooftop of the Simeon Fongang Atmosphere and Ocean Physics Laboratory

(LPAOSF), located on the western corniche of Dakar, Senegal in November 2019. In this study, we analyzed two years of Pandora NO2 and SO2 total columns measurements in Dakar, Senegal and compare these data with those of TROPOMI. The spatial distribution of the total column of SO2 and NO2 measured by TROPOMI showed a strong signal over the industrial area, the port and the urban area near to the Pandora site. We found diurnal, day-of-week, and seasonal patterns, which reflect anthropogenic emissions patterns, especially from local traffic and industries. We noted also that NO2 levels generally decreased during the COVID-19 shutdown period. The same thing is observed with the SO2 total column. Results showed a good agreement between the Pandora and TROPOMI with an underestimation of Pandora by a factor of two.

Poster Session / 58

Analysis of the contribution of the main emission sources from the chemical composition of PM2.5 in Abidjan and Korhogo (Cote d'Ivoire)

Author: Sylvain Gnamien[1]

Co-authors: Cathy Liousse [2]; Véronique Yoboué [3]; Sékou Keita [4]; Julien Bahino [3]; Siélé Silué [4]; Eric Gardrat [2]; Kassamba Mohamed Lamine Diaby [3]

[1] *University Felix Houphouet-Boigny (Cote d'Ivoire) / University Paul Sabatier Toulouse III (France)*

[2] *Laboratoire d'Aérologie, Université Paul Sabatier Toulouse III CNRS, France*

[3] *Laboratoire des Sciences de la Matière, de l'Environnement et de l'énergie Solaire, Université Félix Houphouët-Boigny*

[4] *Université Péléforo Gon Coulibaly de Korhogo, Unité de Formation et de Recherche des Sciences Biologiques*

Corresponding Author: gnkonans@gmail.com

As part of the project Pollution de l'Air et Santé dans les milieus Urbains (PASMU), several equipment's have been installed in order to study atmospheric chemistry (rain, gases and aerosols).
At the installed sites, PM2.5 aerosol samples (aerodynamic diameter less than 2.5 µm) were collected on quartz filters and Teflon filters, weekly at one site in Abidjan and another in Korhogo. Analysis of the samples on us allowed us to determine the chemical composition (mass concentrations, BC, OC and soluble ions) of PM2.5. These data allowed us to study the evolution of the contribution of the sources from the chemical composition. This database will allow us to analyze the chemical closure of the PM2.5 aerosol. In addition, using the EPA PMF 5.0 software, from the United States Environmental Protection Agency, the different sources that contribute to the PM2.5 aerosols collected at the study sites have been studied.
The results show that the concentrations observed during the 2 dry seasons are significant compared to the wet seasons. The analysis of the contribution of the sources, allows to identify 5 sources as well in Abidjan as in Korhogo. The contributions of these sources are very disproportionate, with 40% for traffic and domestic fires in Abidjan, while in Korhogo domestic fires and biomass burning contribute 70% and traffic 16%.

Poster Session / 59

ANALYSIS OF SHORT-TERM PM2.5 MONITORING DATA FROM LOW-COST SENSOR NETWORKS IN GHANA: A CASE STUDY IN ACCRA-TEMA AND GREATER KUMASI METROPOLITAN AREAS

Author: Mathias Borketey[1]

Co-authors: Emmanuel Appoh [2]; Reginald Quansah [3]; Allison Hughes [4]

[1] *Environfin Consult*

[2] *Environfin Consult/CAMS-NET*

[3] *CAMS-Net /University Of Ghana*

[4] *CAMS-NET AfriqAir/University Of Ghana*

Corresponding Author: eeappoh@yahoo.com

Air pollution, particularly in metropolitan areas, is gaining significance in Ghana with concomitant burden of diseases and premature mortality. This study aimed to analyze air pollution data in key metropolitan cities in Ghana focusing on PM2.5. Daily PM2.5 samples were collected from 14 low-cost sensor networks deployed at eight residential, one commercial, three roadside, and two industrial locations in Accra-Tema and Greater Kumasi metropolitan areas, from January to June 2022. The datasets were analyzed using descriptive statistics, Box and Whisker plots, temporal variation, and calendar plots. Mean PM2.5 levels measured during the dry season (January-March) were more than twice (53%) higher than those found during the rainy season (April-June). Daily mean PM2.5 concentrations in Accra-Tema ranged from 34.24 � 27.25 �g/m3 (CPC) to 52.05 � 44.25 �g/m3 (Chalton), while Kumasi varied from 48.90 � 34.48 �g/m3 (Suame) to 57.30 � 40.60 �g/m3 (Asokwa). The variation in PM2.5 values between metropolitan areas revealed a strong influence of different local emission sources on the distribution of PM2.5 concentrations at the various receptor locations. The results showed that PM2.5 concentrations in all study locations exceeded the World Health Organization guideline of 10 �g/m3. However, 86% of the PM2.5 datasets exceeded the Ghana Standard level of 35 �g/m3, with 57% occurring in the Accra-Tema area and 29% occurring in the Greater Kumasi area. The findings of this study will contribute to bridging the data gap and provide a clear understanding of the state of air quality in the country's coastal and middle belt zones.

Poster Session / 60

Development of city level emission inventories for Abidjan and Modeling particulate pollution at this urban area.

Author: Sekou KEITA[1]

Co-authors: Cathy Liousse [2]; Kumar Rajesh [3]; Madina Doumbia [4]; N'doufou Gnamien [5]; Siélé Silue [4]; Véronique Yoboue [6]

[1] *University Peleforo GON COULIBALY, Korhogo, Côte d'Ivoire*

[2] *Laboratoire d'Aérologie, Université Paul Sabatier Toulouse III CNRS, France*

[3] *Research Applications Laboratory, National Center for Atmospheric Research, Boulder, USA*

[4] *Université Péléforo Gon Coulibaly de Korhogo, Unité de Formation et de Recherche des Sciences Biologiques*

[5] *Université Félix Houphouët-Boigny*

[6] *Université Félix Houphouët-Boigny, LAPA-MF*

Corresponding Author: sekkeith@yahoo.fr

West Africa suffers from poor air quality due to the influence of high local emission sources and transboundary emissions from the rest of Africa. A fine resolution of anthropogenic emissions inventory is a prerequisite for accurate air quality modelling. However, there is a lack of inventories for West African cities. In the framework of Air Pollution and Health in Urban Environments (PASMU) project, we have developed new fine-scale spatialized anthropogenic emission inventories at a resolution of 1km by 1km for Abidjan city in Cote d'Ivoire. This emissions inventory includes aerosols (BC, OC and PM2.5) and gases (CO, NOx, SO2 and NMVOC) and takes into account six activity sectors (residential and commercial, industry, energy, transportation, open waste burning and re-suspended road dust). The methodology used to derive this emission inventory is based on national activity databases for traffic, residential/commercial and waste burning consumption estimates and on DACCIWA emission data (Keita et al., 2021) for industries and thermal power plant sources in Côte d'Ivoire. The spatial distribution keys used depend on the activity. For example, domestic fires (residential and commercial) used population density associated to poverty indexes while road density and occupancy are used for traffic. Such urban inventories will be presented and compared to previous regional inventories. We will discuss the relative contribution of different emission sources, highlighting mitigation actions for these sources to improve air quality as scheduled in our new APIMAMA project. Finally, we will present the result of the first modeling exercise

that has been conducted using WRF-chem and the simplified GOCART aerosol model to simulate carbonaceous aerosols, sulphate, dust, and sea salt.

Poster Session / 61

Assessment Of Diurnal and Seasonal Variation of Ambient Particulate Matter (PM2.5) In Juja, Kenya

Author: Josephine Kanyeria Ndiang'ui[1]

Co-authors: Paul Njogu [1]; Westervelt Daniel [2]

[1] *Jomo Kenyatta University of Agriculture and Technology*

[2] *Columbia University*

Corresponding Author: jkanyeria@gmail.com

Air pollution is a major environmental concern that affects human health worldwide. Despite recent studies indicating ambient air pollution is a growing global concern strongly linked to rapid global urbanization, little has been done to monitor the air quality levels in towns outside Nairobi, Kenya. Juja is one of the largest growing towns subjected to increased population, intense human activities and located along the busy Thika Superhighway. Thus, the purpose of this study was to assess the diurnal and seasonal variations of Ambient Particulate Matter (PM2.5) in Juja, Kenya. The data was collected from November 2019 to April 2021 in various residential areas and along the busy Thika Superhighway using the Purple Air Monitoring Sensor. Results showed that PM2.5 concentration was higher in the dry season compared to the wet season and exceeded the WHO guideline. The study found that PM2.5 levels were highly correlated with vehicle emissions, particularly along the busy highway. The PM2.5 levels also peaked twice a day due to morning and evening traffic. The use of low-cost sensors provides increased availability of data and can be used to inform urban planning and environmental policies. This research provides an important tool to address air pollution issues and improve the health and well-being of urban residents.

Panel Discussion / 62

Sensors.AFRICA: Using citizen science as an advocacy tool for a better environment

Author: Constant Cap[1]

[1] *Code for Africa*

Corresponding Author: constant@codeforafrica.org

Cities in the global south face an array of challenges across the socio-economic ladder including resource depletion, increase in slum dwellers, air, noise and water pollution and rising urban poverty (Arku, G. and Marais, L. 2021). These cities are also growing without adequate urban planning and are susceptible to environmental pollution and climate change impacts.

Environmental monitoring is crucial in identifying the impact of pollution on human health and the surroundings. This can also help identify the sources or causes of pollution and avoid debate that might hamper progress in this campaign (Clean Air Catalyst. (2022.).

The involvement of communities in this process can lead to increased awareness, enhanced data collection, and more informed decision making. Community engagement can take many forms, including educational programs, participatory mapping, citizen science initiatives, and technology-based solutions. Citizen science initiatives have proven to be effective in engaging communities in environmental monitoring, in particular air quality monitoring. These initiatives allow community

members to collect and interpret data themselves, which can help attain a greater sense of ownership and responsibility for the environment.

This case-study looks at the work done by Code for Africa's sensors.AFRICA citizen science initiative. The study will discuss the methodology, benefits and challenges of engaging communities in environmental monitoring. It involves understanding pollution within lower middle and low income areas in Nairobi through grassroots community groups, NGOs and journalists.

The methods used include on field participatory mapping techniques, the use of questionnaires to understand the lived experiences and the deployment of locally designed-designed and assembled low-cost sensors. Others are experiences of reporting using local media houses and newsrooms, issuing regular data reports and training on how to interpret data.

The participatory methods showcase the deep understanding of the local situations with independent local correlations emerging from the exercise. Through sensors.AFRICA, the resulting data has been instrumental in bringing proactive change from the community and by the civil authorities. Engaging the communities with active data and sharing this with both authorities and media houses has helped in bringing this change including control of emissions, shutting down of polluting factories and increased awareness of the dangers of air pollution among the general citizenry.

The methods in this case study can be replicated in other African countries where those from marginalized groups, especially women, persons with disability and the poor continue to be the largest victims of environmental pollution in urban areas. The case-study is an indicator that using citizen science can enhance participation in environmental management, more so in what seem to be unplanned and deprived neighbourhoods.

Key Words: Environment, Community

Poster Session / 63

Mapping sources of Air Pollution and identification of vulnerable populations in the Cape Coast Metropolis

Author: Kelvin Yeboah[1]

Co-authors: Adeladza Kofi Amegah [1]; Priscilla Afriyie Adomako [1]

[1] *Public Health Research Group, Department of Biomedical Sciences, University of Cape Coast, Cape Coast, Ghana.*

Corresponding Author: kyeboah@stu.ucc.edu.gh

BACKGROUND
Addressing the health burden from air pollution exposure in low/middle-income countries requires air quality monitoring. However, many African countries lack the resources for comprehensive monitoring. This study aimed to map air pollution sources in the Cape Coast metropolis, to gain insights into the major sources and inform control policies in the metropolitan area.
METHODS: Ground-level visual identification of air pollution sources were identified in three high-pollution areas in Cape Coast: Abura, Kingsway, and Science UCC. The geographic locations of the air pollution hotspots were recorded using the Ghana Postal Service GPS, and local populations exposed to air pollution were also identified.
RESULTS: We found the major source of air pollution across the three sites to be vehicular traffic. Not surprising as these sites are the commercial hub of the metropolis. Biomass burning for commercial cooking and fish smoking was another major source of air pollution in two of the sites; Abura and Kingsway. Biomass fuel and garbage burning in households in the area were also significant contributors of air pollution in all three sites. Street vendors, market women and commuters were identified as the most affected population in the study areas.

CONCLUSION: The main sources of air pollution in the Cape Coast metropolis are vehicular traffic from polluting fleet of vehicles i.e., taxis and tro-tros, biomass burning for commercial cooking and

fish smoking and household air pollution. Addressing air pollution in the metropolis requires development of policies by metropolitan assembly to target these sources and also ensuring regulatory monitoring.

Poster Session / 64

Low-cost sensors development and deployment - a case study

Author: Gideon Maina[1]

[1] *sensors.AFRICA - Code For Africa*

Corresponding Author: gideon@codeforafrica.org

Air pollution is a growing environmental challenge in urban areas globally. Among the affected areas are in Sub Saharan Africa, where outdoor air pollution is responsible for approximately 49,000 deaths annually (World Bank, 2012). In response to this, researchers, civic groups and local governments have embarked on air quality monitoring programmes. Reference grade monitors, which tend to be very costly, pose a challenge for interested parties due to limited resources available within the region. This has led most parties to opt for low cost air-quality monitors in the affected areas. The low cost monitors offer an opportunity to get real time data that can help in the campaign to reduce air pollution.

The operations of these monitors, however, face various challenges including haphazard power supply and unreliable wifi connectivity. This calls for alternative approaches to be adopted in developing monitors. As a result of this, it is necessary to explore alternative sources of power and network service providers to guarantee consistent and constant data collection. This is especially important when doing air quality monitoring in low income areas and public spaces.

As such, the installation of traditional low-cost sensors will require the use of alternative sources of power and network solutions. Among the alternative technologies that have been explored include use of solar panels and batteries as power sources. Researchers and technologists select the wattage of the solar panels depending on the number of sensors incorporated and overall power consumption of the interfaced system. The current draw for a typical low-cost particulate matter sensor ranges from 50mA to 200mA. When a GSM module is incorporated for transmission of real-time data, an extra battery and higher-wattage solar panel may be necessary due to frequent transmission power bursts reaching 2A. All solar panels require a battery with an acceptable capacity up from 10000mAH, which can cater for the energy demands for at least a day; this however is subjective to the use-case.. Applications that do not need real-time data have lower energy requirements, and a memory card can be used to log data that is sent at certain intervals, such as hourly or half daily. Case studies of these can be seen in the sensors.AFRICA outdoor air quality monitor and indoor air quality monitor respectively.

Additionally, NB-IoT, LTE-M, LoRa and Sigfox offer reasonable alternatives for network provision. They fall under the category of Low-Power Wide Area Networks (LPWAN). NB-IoT is a subset of LTE that uses a narrow band of 200kHz designed for low-power network applications. This standard uses less bandwidth than the designated/stipulated bandwidth for that channel. Therefore, it is suitable for real-time data transmission due to its relatively low latency. LoRa, on the other hand, is a low-power wide area network standard that offers a longer range than NB-IoT. On top of that, it guarantees a longer battery life, which adds to the solutions surrounding power issues. Sigfox is also a worthy alternative to LoRa as it offers extended range and leverages on an existing network.

Poster Session / 65

Assessment and projection of a National Air pollution Monitoring Network. The Angola Case

Author: Evanilton Pires[1]

[1] *Instituto Superior Politécnico Tundavala*

Corresponding Author: pires.evanilton@gmail.com

Air pollution observations are primordial to establishing base knowledge about the conditions of an area. Monitoring networks using Low-Cost Sensors cover localized points, and the collection of representative spatial data becomes a limitation for studying large areas and possible existing relationships due to spatial heterogeneity. The present work attempts to develop indicators of the spatial representativeness for a nationwide network and evaluate the representativeness of an existing air pollution monitoring network while experimenting with two hypothetical scenarios with total provincial and municipal coverage. A spatial analysis approach is used, based on Thiessen Polygon interpolation (Nearest Neighbor), with the GDAL library, in QGIS, which allows the calculation of areas assigned to each monitoring site and related statistics as indicators. The resulting network design varied from 7 sensors (existing network) to 25 and 170 sensors for the provincial and municipal scenarios, respectively. In the same order, the minimum covered area reduced from 194 to 36 and 16 Km2/sensor, and the maximum areas from 191 579 to 167 603 and 40 747 Km2/sensor, while national coverage increased from 39% to 78% and finally 98%. It becomes clear that spatial representativeness indicators (minimum, maximum, and relative areas covered) improve the more distributed the monitoring is. However, this improvement needs to be compromised with the requirement of more equipment to increase coverage when resources are limited. This method may be used as a simulation to assess needs or paths for infrastructure growth and the pursuit of network optimization, benefiting both representation and economic analysis.

Poster Session / 66

Schoolchildren don't choose the air they breathe: Policy implications to reduce air pollution exposure in African schools.

Author: Egide Kalisa[1]

[1] *University of Toronto*

Corresponding Author: kalisa.egide@gmail.com

Much of the existing research on school air pollution and children's exposure has focused on developed countries. The present study examines air pollution in the classroom and outdoor schoolyards. The study investigates air pollution and schoolchildren exposure in a region where air quality is understudied and thus far less understood. The concentrations observed for particulate matter air pollution in classrooms are far higher than those reported in the literature for higher-income countries. We summarize policy implications to reduce air pollution exposure in African schools.

Poster Session / 67

Assessment of community knowledge, attitudes and practices on indoor air pollution due to solid fuel smoke as a risk factor for Respiratory tract infections in Amai Village, Amolatar District -Uganda

Author: Ashaba Syson [1]

[1] *Karoli Lwanga Hospital Nyakibale*

Corresponding Author: ashabasyson@gmail.com

Globally, about a half of households in developing countries rely on solid fuel as a primary fuel for cooking and heating. Burning solid biomass fuel produces emissions like particulate matter, carbon monoxide, polycyclic aromatic hydrogen carbons which contribute to toxic air pollutants that are harmful to human health. Consequences attributed to Indoor air pollution include: pneumonia, stroke, ischemic heart diseases, chronic pulmonary disease,low birth weight, cataract and nasopharyngeal infections. In a research carried out in Amai Community Hospital and Amai Village Amolatar District, Respiratory tract infections were the commonest diseases with indoor air pollution as an associated factor. In Amolatar district, no studies had been carried out on household air pollution as a risk factor for the increased Respiratory tract infections due to solid fuel smoke. This study was conducted to assess community knowledge, attitudes and practices on indoor air pollution due to solid fuel smoke so as to provide evidence based information that will trigger policy change and minimize use of solid fuel in Amai Village Amolatar district.
This cross-sectional study employed mixed methods. Semi structured questionnaires were used to collect quantitative data while key informant interviews and focus group discussions were used to collect qualitative data. analysis of data was done.
It was found out that majority had ample knowledge about dangers of solid fuel smoke such as eye diseases, cough and headache. Many had acquired knowledge mainly from radios and televisions, and a significant number knew different sources of heat with less or no smoke such as electricity. Majority had positive attitude towards use of clean solid fuel such as electricity. In addition, majority had good practices towards reduction of indoor smoke like opening windows and putting off fire after cooking. However, many still used firewood for cooking in their households. Therefore, there is need to sensitize household members on the available clean solid fuel sources in order to reduce solid fuel smoke.

Poster Session / 68

Model Evaluation of Optical Counter Derived PM2.5 Concentrations with a Beta Attenuation Monitor (BAM) data in Nairobi, Kenya

Author: Moses Njeru[1]

Co-authors: Ian Kaniu ; Michael J. Gatari

[1] *University of Nairobi Institute of Nuclear Science and Technology*

Corresponding Author: moses_njeru@students.uonbi.ac.ke

Introduction
Particulate matter (PM2.5) is known to have adverse health effects on human health and to impact on climate. For human health concerns the type of involved measuring instruments are expensive and in the low- and middle- income countries (LMICs), they are very few thus inhibiting implementation of dedicated studies. Well calibrated OPCs can offer indicative PM2.5 data that can be used in modelling ground concentrations and reverse the perennial paucity of data in LMICs. This report is from a short study carried out in Nairobi, Kenya, using AlphaSense optical counters (OPC-N2).
Methodology
Five OPC-N2 were collocated with a BAM-1020 at the top of the Engineering Building, University of Nairobi, about 20 m above ground level. They were placed a few feet from each other to ensure free flow of air (Pope et al., 2018). Simultaneous measurements were carried out for one month (September 2021) and weather data was retrieved from an AlO 2 Sonic weather sensor at the same site. The data from the OPCs was compared with the BAM data by employing two linear regression models and three machine learning techniques.
Results
Generally, similar patterns of concentrations were observed (Fig. 1). However, the OPCs data was much lower than the BAM data,

highlighting the inferior measurement technique in OPCs.
The plots suggest the existence of two profiles one at low humidity and the other at high humidity (Fig. 2). At high relative humidity the lower concentrations of PM2.5 from the OPCs correlate more with the higher concentrations from the BAM (Crilley et al., 2018).
Table 1: Performance of different models used to calibrate Alphasense OPC-N2s
The best performing models for most OPCs were the machine learning techniques with the kNN model showing the highest R2 value and lowest MAE and RMSE for three of the sensors (see Table 1). Different calibration models were developed for each of the OPC as opposed to an average approach or using one model for all (Báthory et al., 2022; Magi et al., 2020).

Conclusion and Recommendations

The multilinear regression, the random forest, k nearest neighbor and the gradient boost models account for the influence of meteorological conditions on the PM2.5 measurements and result in better agreement between sensor and reference grade monitors than simple linear regression model.
Future studies should use a longer calibration period that covers all seasons to improve understanding the influence of meteorological variables on OPCs. Although this is well documented in literature machine learning modelling approach has not been used for calibration in Nairobi.
Calibrated OPCs will help in mining particulate data where it is scanty or does not exist.

References

Crilley et al. (2018). J. Atmospheric Measurement Techniques, 709-720.
Pope et al. (2018). J. Atmospheric Chemistry and Physics, 18(20), 15403-15418.
Báthory, C., Dobó, Z., Garami, A., Palotás, Á., & Tóth, P. (2022). Journal of Environmental Management, 304, 114158.
Magi, B. I., Cupini, C., Francis, J., Green, M., & Hauser, C. (2020). Aerosol Science and Technology, 54(2), 147–159.

Panel Discussion / 69

Data driven rational use of resources to develop an air quality management program for Kampala City, Uganda.

Author: ALEX NDYABAKIRA[1]

[1] *Kampala Capital City Authority*

Corresponding Author: andyabakira@musph.ac.ug

Air quality monitoring in Uganda started in 2018 with a single reference station at the US embassy in Kampala. Following the data from this monitoring station, a delegation comprised of political leaders and senior technical officers conducted a learning tour to the USA. Upon their return, the leaders then made a resolution to start an air quality management system for the city. A decision was taken to prioritize air quality management for the city. This resulted into the development of air quality management governance framework which kick started air quality management for the city. This was
followed by the following: 1) baseline study to establish pollution levels and locations of the sensors (to be procured) in the city in 2018; 2) installation of low cost monitors in 2019; 3) studying longitudinal temporal and spatial variation of air pollution in the city in 2019-2021; 4) utilizing the results from the natural experiment of COVID-19 induced lockdowns to understand associations; 6) development of the Kampala city clean air action plan in 2022 7) development of air pollution control

regulations;7) source
apportionment assessment and emission inventory in 2023.

Our next steps are now concentrated on implementation of the clean air action plan while tracking the progress from the senor network. We aim to expand the scope of the monitored pollutants to include more gases, improve and increase data use to inform policies and raise awareness about air pollution control amongst the city residents. We are also currently using this data to mobilize resources from donors and partners to better address air pollution in the city.

70

"How to access free data from the Copernicus Atmosphere Monitoring Service (CAMS)

Online training session from Chris Stewart